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ABSTRACT

A study examined the correlation between mathematics achievement and television viewing, and explored the underlying processes. Data were gathered from 13,542 high school seniors from the first wave of the High School and Beyond project, conducted by the National Opinion Research Center on behalf of the National Center for Education Statistics. A neural network was used for the analysis. Unlike methods employed in prior studies, with no a priori assumptions about the underlying model or the distributions of the data, the neural network yields a correlation impervious to errors or inaccuracies arising from possibly violated assumptions. Results indicated a curvilinear relationship, independent of viewer characteristics, parental background, parental involvement, and leisure activities, with a maximum at about one hour of viewing, and persistent upon the inclusion of statistical errors. The choice of mathematics performance as the measure of achievement elevated the found curvilinearity to a content-independent status, because of the lack of television programs dealing with high school senior mathematics. Results also indicated that the curvilinearity was replaced with entirely positive correlation across all hours of television viewing for lower ability students. A host of intervening variables, and their contributions to the process were examined. Finding suggest that the process, and especially the component with a positive correlation, involved only cortical stimulations brought about by the formal features of television programs. (Contains 37 references, 1 table, and 6 figures of data. An appendix compares neural networks and some conventional methods.) (Author/RS)

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Television Viewing and Mathematics Achievement

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Abstract

This study examines the correlation between mathematics achievement and television viewing, and explores the underlying processes. The data consists of 13,542 high school seniors from the first wave of the High School and Beyond project, conducted by the National Opinion Research Center on behalf of the National Center for Education Statistics. A neural network is employed for the analysis; unlike methods employed in prior studies, with no a priori assumptions about the underlying model or the distributions of the data, the neural network yields a correlation impervious to errors or inaccuracies arising from possibly violated assumptions. A curvilinear relationship is found, independent of viewer characteristics, parental background, parental involvement, and leisure activities, with a maximum at about one hour of viewing, and persistent upon the inclusion of statistical errors. The choice of mathematics performance as the measure of achievement elevates the found curvilinearity to a content-independent status, because of the lack of television programs dealing with high school senior mathematics. It is further shown that the curvilinearity is replaced with an entirely positive correlation across all hours of television viewing, for lower ability students.

A host of intervening variables, and their contributions to the process, are examined. It is shown that the process, and especially the component with a positive correlation, involves only cortical stimulations brought about by the formal features of television programs.

Statement of the Problem and

Related Research

The significance of this study derives from the statistic indicating that by the time of high school graduation, the average individual will have spent more hours viewing television than in the classroom (Fosarelli, 1986; National Institute of Mental Health, 1982). Moreover, data indicating a steady increase in the amount of time children and teenagers in the United States spend watching television (Comstock & Paik, 1991), coupled with the constant decline in American student's Scholastic Aptitude Test scores (National Commission on Excellence in Education, 1983) and American students' lower than desired achievement scores in mathematics and science in comparison to their foreign counterparts (Stevenson, 1983; Walberg, 1984), make the correlation between television viewing and academic performance one deserving of careful scrutiny.

The significance of the issue goes beyond its theoretical importance. A proper understanding of the relationship between television viewing and achievement could have applied value. A negative correlation between television viewing and academic achievement might call for restraint at home or some other type of guidance and supervision. A null correlation might lead to redirection of energy and attention to other factors contributing to academic achievement. A positive correlation might provide a basis for enhanced use of television in education. In light of the social significance of the issue, concerns about the amount of time children spend watching television, and the possibility that such consumption may be affecting achievement, the study reported, herein, was undertaken.

Television and School Achievement

Questions about the influence of television on school achievement have been debated and investigated ever since the medium was introduced (Beentjes & Van der Voort, 1988; Gaddy, 1986). Studies of the relationship have produced inconsistent findings. Some have shown that television helps students increase their levels of learning. Others suggested that television viewing inhibits or interferes with academic achievement. Still others have failed to reveal any evidence of a relationship between television viewing and achievement.

Among the studies indicating that television viewing facilitates academic achievement, Greenstein (1954) found that the academic achievement of third to sixth-grade children who watch television was consistently higher than that of the nonviewers. Using nationally used test of general vocabulary, Schramm, Lyle, and Parker (1961) determined that television enhanced the vocabulary in children in communities with television beyond that of their counterparts in communities without television. High and low ability students portrayed a stronger effect than the average ability students. Rice, Huston, Truglio, and Wright (1990) in a two-year longitudinal study of several hundred children discovered that those who viewed Sesame Street regularly had a better vocabulary while viewing of animated cartoons showed no association to later vocabulary levels. The findings suggested that television can enhance achievement in children, but the effect appears to depend on program content.

In contrast, Hornik (1978) analyzed teenagers from El Salvador and found that the reading skills declined with acquisition of the television set. Corteen and Williams (1986) in a three-community natural experiment comparing among the towns just before and two years after the arrival of television produced evidence showing that television affected viewers negatively in reading skills. Children who watched more television tended to be poorer readers than those watching fewer hours, even after the effects of intelligence were removed. This suggests that the arrival of television slowed the acquisition of reading skills.

Keith, Reimers, Fehrman, Pottebaum, and Aubey (1986) used path analysis to study the effects of television viewing time, parental involvement, homework, and other background characteristics (e g., gender, ability, family background) on academic achievement. Based on a sample of more than 28,000 subjects, the strongest direct influence on achievement was intellectual ability, followed by homework, ethnicity, and family background. Television viewing had a small negative effect on achievement. Parental involvement had an even smaller effect.

Himmelweit, Oppenheim, and Vince (1958), in a large-scale inquiry into the introduction of television in Great Britain, reported that television programs sometimes stimulated interests and that these interests were often translated by children, especially teenagers, into subjects they pursued by reading. However, such effects occurred only among those who had no problems with reading, and, therefore, any contributions by such inducements to achievement were null or minor. Childers and Ross (1973), using multiple and partial regression analysis, could find no relationship between television and academic achievement. Sharman (1979), using path analysis, analyzed 271 sixth grade children in Australia, and found no relationship between overall academic achievement and the amount of television viewed. Gaddy (1986) drew samples ranging from about 2,400 to 5,000 from the High School and Beyond study and examined the relationship between television viewing and academic achievement in reading, vocabulary, and mathematics. He used a linear cross-lagged correlation technique while controlling other variables, such as parental involvement, availability of other media, social class, gender, ethnicity, and educational resources. No clear evidence that television affects achievement surfaced.

Some studies have produced evidence of a curvilinear relationship between television viewing and achievement, with achievement rising with a few hours per day of television viewing and then falling to considerably lower levels continuously as viewing increases further (see Figure 1).[1] Morgan and Gross (1982) in a cross-sectional analysis of over 600 sixth through ninth graders, found a correlation between viewing and achievement that varied as a function of social class, mental ability, and gender of the subjects. Among these, some were curvilinear. Fetler (1984) in his analysis of the 1981 California Assessment Program (CAP), considered achievement in reading, writing, and mathematics and concluded that there was some evidence of curvilinearity, but only for lower socioeconomic status students. Potter (1987), examining about 550 pupils between the eighth and twelfth grades, found that achievement peaked at about 1 1/2 hours per day, and then declined as exposure increased. In contrast, Neuman (1988) found from her eight-state pooled data a curvilinearity that was most pronounced at the intermediate, less so at the elementary, and not at all at the high school level. The same pattern was recurrent when socioeconomic status and gender were controlled.

One possible source of these conflicts, either regarding the direction of the correlation or the existence of the curvilinearity, has been attributed to the diverse methodological strategies, i.e., methods of collecting data, sample sizes, the criterion measures, and different intervening variables chosen (Beentjes & Van der Voort, 1988; Hornik, 1981; Potter, 1987). To overcome this problem, a meta-analysis was conducted by Williams, Haertel, Haertel, and Walberg (1982) on 23 studies investigating the relationship between television viewing and academic learning. Considering varying study characteristics and methodological characteristics, and assuming a linear fit they found a small, overall negative effect of television viewing on scholastic achievement. Upon further investigation, they determined that the shape of the relationship was, in fact, curvilinear. However, as will be discussed later, they were unable to establish the magnitude of this effect, due to shortcomings of their coding method.

This curvilinear relationship, discovered by relaxing the assumption of linearity, resolves a number of the inconsistencies that have been found between studies, and even within given studies. By the very definition of "curvilinear" (see footnote 1), it incorporates a positive correlation, a null correlation (at the threshold), and a negative correlation in a self-consistent manner. It brings to light the possibility that some inconsistencies are due to inappropriate assumptions made in some of the studies. In other words, it may be that certain assumptions of the model have been violated by the data; all conventional models have inherent assumptions, whose violation may lead to erroneous conclusions. Indeed, even the aforementioned methods yielding evidence of a curvilinear correlation are grounded in assumptions that are often violated. That NO conventional model is free of assumptions renders this possibility a persistent source of error.[2] By contrast, a neural network is a non-analytic model based purely on raw data and free of all assumptions, thereby adding confidence to the validity of the results derived therefrom.

The substantive significance of a curvilinear relation (Figure 1) between achievement and television viewing is not debatable, for a positive correlation and a negative correlation, both, can have practical implications in education. What is debatable is the exact shape of the curvilinearity, in an assumption-free context. The existence of the falling segment is less questionable, because the fall is large enough to not be obscured by statistical errors, and large enough to be detected by linear models. Also, the falling segment has been predicted by well-tested hypotheses, such as displacement hypothesis and concentration deterioration hypothesis (see processes, below). The rising segment, however, is small enough to be obfuscated by statistical errors, or be distorted by the restrictions (assumptions) of the model. As a result, in this study, a neural network was employed to provide an assumption-free model, and an error analysis of the results was performed, to derive the exact shape and magnitude of the correlation between television viewing and achievement. The measure of achievement itself was taken to be mathematics performance.

Based on prior discussions and rationales, the following question was asked:

Research Question 1: What is the exact relationship between mathematics achievement and television viewing?

Our intent to resolve the inconsistencies in the literature, and to derive the exact correlation was not purely for the sake of self-consistency in understanding - although that alone would suffice - but also for exposing any processes involving academic achievement and television viewing that may be utilized to affect the former positively.

Theoretical Perspectives and the Processes

A variety of hypotheses have been proposed to explain both positive and negative correlations. Hornik's (1981) review outlines six, and more recently Gaddy (1986) and Beentjes and Van der Voort (1988) have supplemented the list with three additional hypotheses. The primary concern of these hypotheses is the correlation between television viewing and reading achievement, while mathematics achievement has attracted less interest. Assuming the existence of a unique underlying process governing television viewing and overall achievement, the model investigated in this study employed the same hypotheses to understand the correlation between television viewing and mathematics achievement.

Four hypotheses that would lead one to expect a negative correlation between achievement and television viewing are the Displacement Hypothesis, the Concentration-Deterioration Hypothesis, the Passivity Hypothesis, and the Hemispherical Specialization Hypothesis.

The Displacement Hypothesis proposes that television displaces time that could be spent on school-helping activities (Corteen & Williams, 1986; Gaddy, 1986; Neuman, 1988). The Concentration-deterioration Hypothesis argues that the perceptually demanding, rapid pace of television programs leaves students no time to reflect or understand what they are learning (Gadberry, 1980; Greenfield, 1984; Singer & Singer, 1979; Singer, 1980; Winn, 1985). Students who are used to such rapid pace of features of the television medium would expect the same pace from school education and, if not provided, become bored and intolerant of schooling. Gadberry (1980), however, argued that this intolerance is a content effect, not a medium effect. In contrast, the remaining two hypotheses (yielding a negative correlation) are based on the formal features of television programs. The Passivity Hypothesis suggests that watching television induces children to become mentally lazy (Postman, 1982, 1983). It argues that children process information from television programs without much mental effort. Both children (Beentjes & Van der Voort, 1988; Salomon, 1984) and adults (Csikszentmihalyi & Kubey, 1981) have been found to invest less mental effort in watching television than in reading. In view of the Hemispherical Specialization Hypothesis, high doses of television viewing overstimulate the right brain hemisphere, which is functionally specialized in processing visual and spatial information. Therefore the activities of the left hemisphere, which regulates the processing of language, is reduced or even eliminated. This would leave children less capable of processing language (Winn, 1985; Zuckerman, Singer, & Singer, 1980).

The same processes that render the Hemispherical Specialization Hypothesis an inhibitory theory in regards to reading achievement, would result in a positive correlation between television viewing and mathematics achievement; the reason being the overstimulation, and the specialization of the right brain in the processing of symbolic information.

Five more hypotheses that would yield a positive correlation between achievement and television viewing are the Interest Stimulation Hypothesis, the Learning of Instrumental Information Hypothesis, the Learning of School-equivalent Content Hypothesis, the Learning of New Cognitive Skills Hypothesis, and the Excitation-transfer Hypothesis.

The Interest Stimulation Hypothesis proposes that television stimulates viewers' interest in ideas and topics that they may pursue in forms other than television, particularly book reading (Hornik, 1981). In this view, it is the content of the viewed programs that would lead, through a variety of intervening factors, to a rise in achievement. This content-effect and similar intervening variables are expounded by the Learning of Instrumental Information Hypothesis, in which television influences achievement as it molds children's thinking about school, influencing their expectations and aspirations (Berry, 1980). Another similar hypothesis, but with no reference to specific intervening variables, is the learning of School-equivalent Content Hypothesis. It suggests that television can be an effective teaching medium for learning school-equivalent content when it is explicitly designed to do so, e.g., Sesame Street (Hornik, 1981).

Appealing to the formal features of television as well as to cortical factors are the Learning of New Cognitive Skills Hypothesis and the Excitation-transfer Hypothesis. The former hypothesis holds that television viewing teaches certain cognitive skills and provides practice in the symbol system, and may allow for the transfer of those skills to the interpretation of other phenomena. For example, symbolic codes, such as zoom-in, can teach cognitive skills of breaking a stimulus into parts, and several different-angle shots of an object can teach the mental skill of perspective taking (Salomon, 1979). The latter proposes that television by its fast pace, visual, attention-catching stimuli, creates a temporary alertness, which, in turn, fosters student's attention and potentially superior learning. Superior information acquisition would result from fast-paced versions of television programs that might affect cortical arousal in the receiver (Zillmann, Williams, Bryant, Boynton, & Wolf, 1980).

Whereas the viewed content has been consistently linked to achievement levels (Rice et al., 1990; Selnow & Bettinghaus, 1982), these hypotheses call attention to an important and unique aspect of television that affects learning, namely the format, or the formal features of television. Television's formal features are visual and auditory production techniques that are content-free; the visual attributes include cuts, dissolves, fades, pans, zooms, wipes, and visual special effects; and the auditory attributes include sound effects, background music, and foreground music. In recent years, many researchers have emphasized the importance of television's formal features, and have investigated how these features are related to viewers' cognitive processing of information (Anderson & Lorch, 1983; Anderson & Smith, 1984; Collins, 1982, 1983; Huston & Wright, 1983, 1989; Salomon, 1979, 1981, 1983, Wright & Huston, 1983; Zillmann, 1982).

A model that encompasses all of the above-mentioned hypotheses is presented in Figure 2.[3] The lines represent correlations and not necessarily causal relations. In this article, and with foresight, only mathematics achievement was considered; this allowed for the isolation of content-effects in the process. The intervening variables were taken to be the following 13 quantities, grouped into 4 classes: gender, ability, ethnicity (viewer characteristics); father's occupation, father's education, mother's occupation, mother's education, socioeconomic status (parental background); parents knowledge of what the student is doing, father's monitoring of school work, mother's monitoring of school work (parental involvement); reading for pleasure, and visiting friends (leisure activities).

The bottom two boxes in Figure 2 represent other intervening variables referring to cortical stimulations of the brain, and other hidden variables that might have been overlooked. Neither is measurable; a measure of cortical stimulations would require a measure of neuronic activity in the cortex - a quantity that varies greatly depending on whether the activity is observed with Nuclear Magnetic Resonance (NMR), Positron Emission Tomography (PET), or a host of other developing imaging techniques. However, as will be seen in the Results section, it was possible to study the contribution of cortical stimulations in spite of the lack of a measure. The hidden variables, by their very definition, are ethereal and entirely unaddressable. One can neither prove nor disprove their existence. The inclusion, in the present study, of all variables appearing in previous research should partially alleviate concerns regarding the existence of any overlooked hidden variables.

Although not explicit in the original statements of these hypotheses, it should be evident that each has a domain of applicability. In other words, the underlying mechanisms must involve not only one of these hypotheses, but perhaps all of them. The simplest coalition among these perspectives would, then, suggest a period of rising achievement levels, while the facilitating hypotheses are at work, followed by a fall in the achievement levels when the inhibitory hypotheses are activated. In this way one can envisage a curvilinear relation of the type suggested by the empirical studies.

It is, then, natural to ask:

Research Question 2: What are the contributions of the intervening variables involved in the process (i.e., Figure 2) governing television viewing and mathematics achievement?

The Statistical "Model": Neural Networks

As already mentioned, ALL statistical models are based on assumptions of varying degrees, but assumptions nevertheless. For instance, linear regression techniques assume that the underlying function, relating the independent variables to the dependent ones, is linear. Non-linear regression overcomes this limitation, but one must still specify the exact function - quadratic, or cubic, etc. - that is to be fitted through the data. Any choice of the function, again, comprises an assumption. Path analysis, also, assumes a linear relation between all the variables. Another example of a model incorporating an assumption, albeit of a different type, is discriminant analysis, where the parent distributions of the data are assumed to be normal. Any violations of such assumptions can lead to false conclusions, or inaccurate results, at best.

Recently, however, an entirely new approach, called the Neural Network approach, has emerged with the promise of a completely assumption-free analysis. Like conventional modeis, it provides a model representing the underlying theory, but in contrast with them, it embodies no assumptions whatsoever. A description of their inner structure can be found in Masters (1983), and some applications in the social sciences, demonstrating their superiority over conventional methods, are in Garson (1991), Paik and Marzban (1994), Van Nelson and Neff (1990), and Woelfel (1993). For the purposes of the present application, the following review is offered:

A Neural Network refers to a collection of some number of variables, interacting with each other. The variables are called Nodes. A particular type of neural network, called a Feed-forward Neural Network, incorporates a given architecture (displayed in Figure 3), wherein the nodes are placed in layers interacting with other layers. Here, the input nodes and the output nodes correspond to the independent variables and the dependent variables of the model, respectively. The hidden nodes have no physical interpretation apart from allowing the network to deal with nonlinearities in the data. There are two stages involved in a neural network analysis - a training stage, and a validation stage. One first trains the network by repeatedly exposing it to data, i.e., the independent and dependent values. This leads to a set of "learned" weights (the ω's in Figure 3) that assure correct values of the output upon exposure to the corresponding inputs. The validation stage involves testing the trained network on data not used in training, in order to assure that the network is capable of prediction and generalization (Masters, 1993). The ability of neural networks to generalize is another virtue that has led to their popularity.

It is possible to make contact with conventional methods. For instance, a network with no hidden layers, and output nodes that take continuous values, is equivalent to linear regression; and if the output nodes are logistic (i.e., 0 or 1), it is equivalent to logistic regression; if the data is also distributed normally, then it is equivalent to linear discriminant analysis. The hidden nodes comprise one element that set neural networks apart from traditional methods. There are many methods by which one can arrive at the correct number of hidden nodes, and one will be described in the next section.

Method

Data

To examine the research questions raised in this study, data were obtained from a large, representative of United States, comprehensive sample of High School and Beyond studies (HSB), the first wave (1980), conducted by the National Opinion Research Center on behalf of the National Center for Education Statistics. The HSB data included information on 28,240 senior students, sampled by a two-stage stratified probability sample of 1,015 high schools. Schools were selected with a probability proportional to their estimated enrollment and within each school, data were obtained on 36 seniors chosen at random (National Opinion Research Center, 1980). For this analysis, seniors who completed and answered all the questions relevant to this study in a meaningful way were included in the analysis, i.e., subjects with multiple punches or missing data were excluded. This left 13,542 seniors for actual analysis. Only senior high school students were chosen since it is for this group that the existence of a correlation has lacked consensus (see Potter, 1987 and Neuman, 1988).

Variables

Based on prior literature, the following variables were selected to examine the underlying processes:

Academic achievement. Academic achievement was measured by mathematics standardized scores (t scores; mean = 50, standard deviation = 10). The mathematics score here was an average of HSB Mathematics I, and Mathematics II standardized tests. The range of the achievement composite score was from 27 to 72.

Television time. Television viewing time was measured by answers to the question, "During weekdays about how many hours per day do you watch TV?" Responses ranged from "don't watch TV during day" (coded 0) to "five or more per day" (coded 6). Intermediate responses were "less than 1 hour," "1 to 2 hours," "2 to 3 hours," "3 to 4 hours," and "4 to 5 hours."

Gender. Gender was either male or female.

Socioeconomic Status (SES). SES was a composite score of father's occupational status, mother's and father's educational attainment, family income, and possessions in the home (whether the family had a daily newspaper, an encyclopedia, a typewriter, two or more cars, more than 50 books, a room of the student's own, and a pocket calculator). Each question was converted to a z score, and then averaged. Based on this standardized scores, each student was classified as belonging to a low, middle, or high SES, depending on whether he/she belonged to the lowest quartile, middle two quartiles, or the highest quartile in the distribution.

Ability. Ability was a composite score of six tests measuring student's verbal and nonverbal abilities: Vocabulary I and II, Picture-number, Mosaic comparisons I and II, and Visualization in three dimensions (cf. Keith, et al., 1986). Each score was standardized (t score; mean = 50, standard deviation = 10), and averaged. The ability variable ranged from 28 to 71.

Ten additional intervening variables (some of which are incorporated in SES above), were ethnicity, father's occupation, father's education, mother's occupation, mother's education (parental background), parents always know what the student is doing, father monitors school work, mother monitors school work (parental involvement), reading for pleasure, and visiting friends (leisure activities).

The Neural Network

The particular neural network employed here, a modified version of that found in Masters (1993), had one output node and it was taken to be the mathematics scores. To obtain the relation between these scores and television viewing, a single input node was taken to correspond to the number of hours (per day) of television viewing. To include more variables, such as gender, SES, and ability, a second input node was introduced corresponding to these variables.

The 13,542 cases were divided into two groups of 10,000 and 3,542 each. The former was used for training the network, while the latter was employed to test the predictive capabilities of the network. Since the achievement scores of the latter group were known, the performance of a variety of networks with differing number of hidden nodes was gauged by allowing them to "predict" the achievement scores in this validation set. The network that yielded the best comparison was then selected as the one with the optimal fit to the data.

Finally, the trained network was utilized by varying the input node from 0 (0 hours of viewing per day) to 6 (5 or more hours of viewing per day), in 0.1 increments, while recording the output (achievement) values. Though the television viewing data was in units of one hour per day, the trained network was capable of generalizing the achievement scores for viewing times of any fraction of that unit.

Results

The results of the neural network analysis indicated that there is a curvilinear relationship between mathematics performance and the amount of television viewing. Additionally, it was shown that this correlation persists when a host of viewer characteristics, parent-related, and leisure-related variables were controlled. This, in conjunction with the content-independence of the effect, suggested a cortical stimulation brought about by the formal features of television programs.

The relationship between mathematics performance and television viewing is presented in Figure 4. This curve is the result of a network with two hidden nodes on a single hidden layer, as this was the optimal network according to the process described in the previous section. As is evident, there exist a maximum at slightly less than one hour of viewing per day. In other words, achievement as measured by mathematics scores first rises for about one hour of viewing per day, and then begins to decrease with further viewing. The rise in mathematics scores over the first hour of viewing is a 3% effect, and the decrease over the next five or more hours of viewing is an 11% effect.[4]

In order to assure that this curvilinearity is not due to statistical errors in the data an error analysis was performed. The neural network estimates of the hourly scores, along with the errors thereof are presented in Figure 4, as well as in Table 1. It is apparent that the curvilinearity cannot be dismissed by the consideration of statistical errors. The errors are too small to account for the rise; the smallness of the errors is due to the high performance of the network and the large sample size. (As mentioned in footnote 3, it was for the reason of having small statistical errors that the number of intervening layers was restricted to one).

Hence, there is a curvilinear relationship between mathematics performance and the amount of television viewing, and that it is not due to statistical errors, nor due to implicit assumptions of the model. This is the answer to the first research question.

Having shown the persistence of the curvilinearity beyond statistical errors and assumptions, it was natural to examine the underlying processes. A step-wise approach was adopted, wherein the contribution of each intervening variable was examined separately. The 13 intervening variables represented viewer characteristics, parental background, parental involvement, and leisure activity variables. An examination of the distributions of all 13 variables for every hour of viewing, revealed some variation for only three - gender, SES, and ability - at different viewing hours. The distributions of the other 10 variables showed no variations at different viewing hours. This proved that the underlying process does not involve any of these variables. It would appear, then, that the underlying process would involve the remaining three variables, and possibly the content viewed. Such possibilities, too, were precluded by considering the correlations for each of the remaining three variables, proving that the curvilinearity persists independent of all such attributes.

The results for gender and SES are plotted in Figures 5, and 6, respectively. The curve in Figure 5 is the result of a network with 3 hidden nodes, while that in Figure 6 is obtained from a network with 4 hidden nodes, both on a single hidden layer. These were found to be the optimal number of hidden nodes. As can be seen, the curvilinearity exists for both genders, as well as for all ranges of SES. Therefore, the shape of the relation in Figure 4 is not due to differences in gender, nor in SES, of the viewers at different viewing hours. It is noted, in passing, that boys portray an overall higher level of achievement than girls, and that achievement increases also with increasing SES. As for the contribution of ability to the correlation, a network with 4 hidden nodes was employed; it found the correlations given in Figure 7 for five different ability levels. Not surprisingly, higher ability students portray higher mathematics scores. More importantly, that there exists a rise in achievement for the entire range of abilities, precludes any dismissal of the rising segment of the curvilinearity based on a priori ability differences in the viewers at different viewing hours. The unexpected positive correlation for the entire range of television viewing hours, for low ability students, will be addressed in the Discussion section.

Finally, given that the measure of achievement was performance in mathematics, and that the population under study was high school seniors, the absence of high school senior level mathematics in television programs proved that the curvilinearity is not due to the content viewed.

What does this independence on all intervening variables mean? In order to answer this question, it is convenient to consider the rising and the falling segments separately. In fact, for this purpose one can approximate the two segments, each, with a straight line:

$$\mathit{Math\ Achievement}(t) = \begin{cases} a_r t + b_r\,, & \mathit{for}\ \ 0<t<1 \\ a_f t + b_f\,, & \mathit{for}\ \ 1<t<6 \end{cases}$$

where t is the amount of television viewing, and a_r, a_f are the slopes, and b_r, b_f are the y-intercepts of the rising and falling segments, respectively. A priori, the a's and the b's could depend on all the intervening variables, as well as on content/format. However, as shown, whereas this may be true of the y-intercepts, a_f does not depend on SES and gender. Most importantly, a_r does not depend on, and therefore cannot be determined by, <u>any</u> of the 13 intervening variables. Assuming the non-existence of hidden variables, this leaves a_r with a functional dependence on only cortical stimulations:

$$a_r = f\ (\text{cortical stimulations})\ .$$

Furthermore, due to the structure of the model considered here (Figure 2), the variables representing cortical stimulations, themselves, may be functions of content and/or format. But, having shown the independence of a_r on content, too, it follows that the rise in achievement is due to cortical stimulations brought about from the viewing of the formal features of television programs.

Therefore, an answer to the second research question is that the process underlying television and mathematics achievement, during the first one hour of television viewing, involves cortical stimulations of the brain induced by the formal features of television programs.

Discussion

The purpose of this study was to explore the relationship between, and the processes governing, academic achievement and varying amounts of television viewing. High school seniors served as subjects, and their achievement was measured by their scores on mathematics tests. The relationship revealed was curvilinear, with achievement increasing for one hour of television viewing, and decreasing steadily with additional viewing time. The relationship persists beyond statistical errors, differences in viewer characteristics, parental attributes, leisure activities, and even the content of the program viewed, suggesting a cortical factor in the process.

Some prior studies, too, have found a curvilinear relationship between academic achievement and television viewing. Morgan and Gross (1982) and Potter (1987) did find a curvilinear correlation; however, their classification of television viewing time - low, medium, high - was too coarse for isolating the threshold value of television viewing. In contrast, Fetler (1984) with a finer scale of television viewing hours, confirmed the rise, followed by the fall, but still did not perform a fit to the data, and used only the <u>mean</u> of the mathematics scores at each hour of viewing. As noted earlier, employing the mean constitutes an easily violated assumption (cf., footnote 2). Also he did not perform an error analysis to assure the existence of the correlation beyond statistical errors. In their meta-analysis, Williams, et al. (1982) were able to estimate the relationship, but without a quantitative measure of achievement. This was because, in coding their studies, they recorded only the correlations between achievement and television viewing and not the achievement scores directly. Hence, their regression function was only the slope of the achievement versus television viewing curve, thereby preventing them from finding the "y-intercept", i.e., the "magnitude" of the overall effect. Finally, any relationship discussed in prior literature, curvilinear or not, is prone to inaccuracies due to the presence of inherent assumptions, making comparisons difficult.

The argument has been made that light viewers may be more discriminating in selecting the programs they choose to view, thereby explaining the increase in achievement levels at one hour of television viewing per day without reference to cortical factors (Comstock & Paik, 1991; Cooper, & Chance, 1983; Hornik, 1978; Potter, 1987; Riddley-Johnson, Selnow & Bettinghaus, 1982; Williams, et al., 1982). However, given the measure of achievement, namely mathematics, and the grade of the students in the sample, namely high school senior, it is difficult to give credence to this argument, since high school senior level mathematics is a topic rarely covered on television.

One may wonder if the 3% rise, or the 11% fall, in the curve in Figure 4 are "socially significant." Such questions cannot be addressed in any meaningful sense; suffice it to say that the identification of the underlying processes can allow one to magnify the effects to any desired degree via manipulation of the factors involved.

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Appendix

In this appendix we compare neural networks and some conventional statistical methods. For further details, see Cheng and Titterington (1994), and Paik and Marzban (in press) for a highly rigorous treatment.

By a "conventional" method of analysis reference is made to those having an analytic framework, where "analytic" means that the method is derived from a set of mathematical equations. For example, the method of Discriminant Analysis begins with a mathematical statement reflecting the normality of the distributions of the data, centered around the mean, μ, with a dispersion matrix Σ:

$$\frac{1}{\sqrt{|\Sigma|}} e^{-\frac{1}{2}(x-\mu)\Sigma^{-1}(x-\mu)} .$$

Regression methods require the specification of the regression equation. In a linear regression equation

$$y = a_1 x_1 + a_2 x_2 + a_3 x_3 + \ldots + a_n x_n + \epsilon$$

one has to specify the $x_1, x_2, \ldots, x_n$ as <u>functions</u> of the independent variables (Draper and Smith, 1981). In a nonlinear regression equation,

$$y = f(x_i, \theta_i) + \epsilon \quad ,$$

the exact nonlinear (in θ_i) function itself has to be specified. In traditional approaches, any choice of these functions constitutes an <u>explicit</u> assumption. In the neural network approach, however, the network parametrizes the space of "all" functions, through the number of its hidden nodes (Hornik, Stinchcombe, and White, 1989). In other words, by simply varying the number of hidden nodes (up to, and excluding, that which overfits) one can systematically search and find the best fit, without making any explicit assumptions regarding the underlying function.

It is often said that the assumption of normality is employed in any method based on the least squares criterion - regression, neural network, or otherwise. However, there, the assumption of normality is implicit, and enters in only establishing the equivalence of the least-squares criterion and the maximum likelihood criterion (Bates & Watts, 1988). (As for neural networks, in fact, there is some evidence that flat distributions are learned more easily (Master, 1993, p.267).) In this sense, both discriminant analysis and regression analysis occupy a separate status in having explicit assumptions about the underlying function and distribution.

Author Note

Dr. Caren Marzban, faculty of the Department of Physics, at the University of Oklahoma, is acknowledged for providing the computer codes for the data analysis.

Table 1

Neural Network Estimates of Mathematics Scores, Errors, ıd Television Viewing Time

Television Viewing Hours	Sample Size (N)	Mathematics Score	Error*
0	304	51.7	.53
0 - 1	1066	53.0	.28
1 - 2	1875	52.0	.21
2 - 3	2246	50.8	.18
3 - 4	1783	49.7	.20
4 - 5	1068	48.8	.26
5 or more	1658	48.1	.20

* $\sigma/(N)^{½}$ is the error of the mean, where σ is the standard deviation of the (hourly) distribution of the difference between the actual and the predicted scores (i.e., residuals), and N is the sample size for each hour.

Figure Captions

Figure 1. Nine hypotheses, their processes, and directions of their implied correlations. The left-most and the right-most boxes represent elements of television viewing and achievement, respectively. The middle boxes represent the specified intervening variables, and the hashed boxes represent an unspecified list of intervening variables.

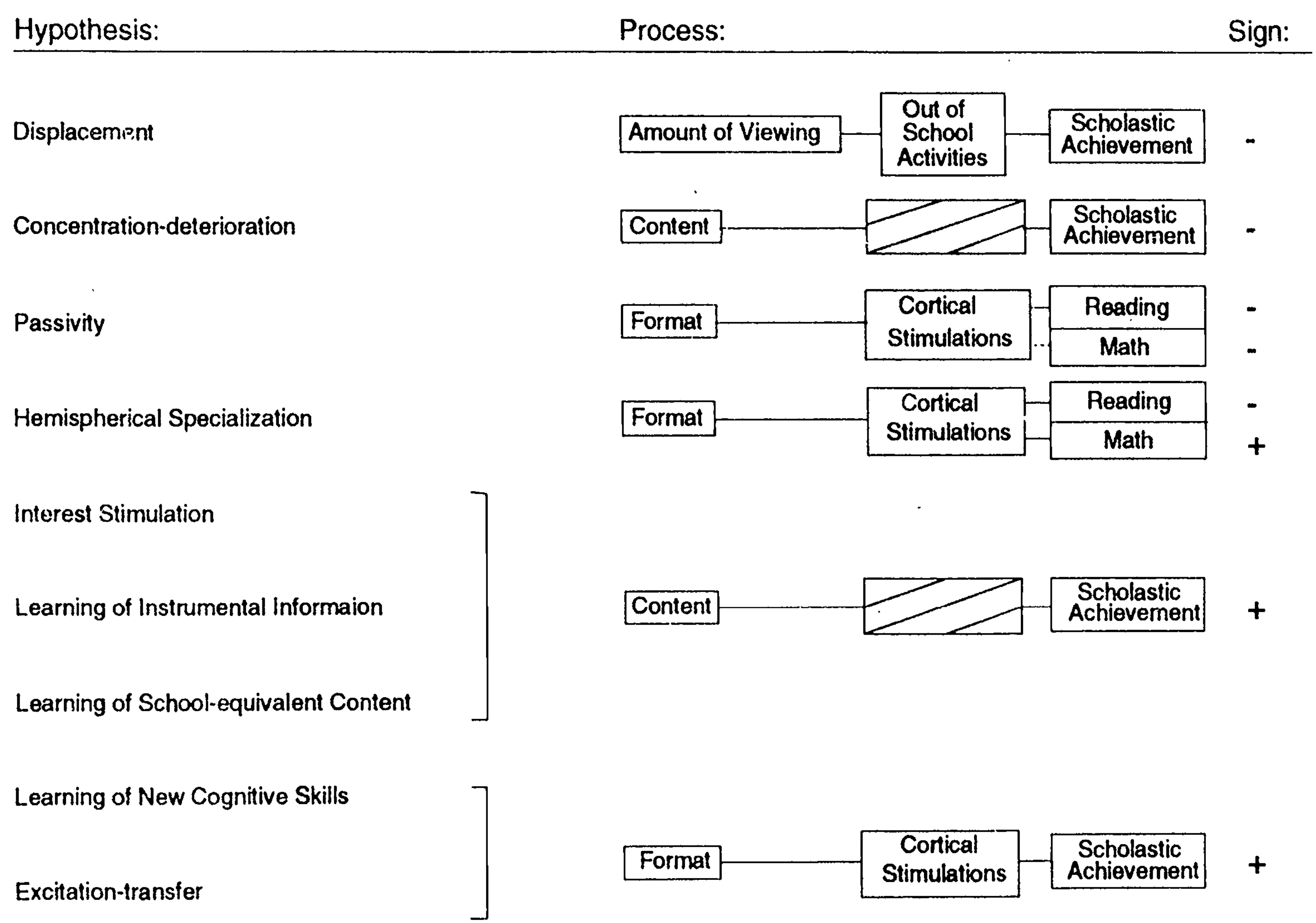
Figure 2. A model encompassing all the hypotheses presented in Figure 1. The lines represent correlations and not necessarily causal relations.

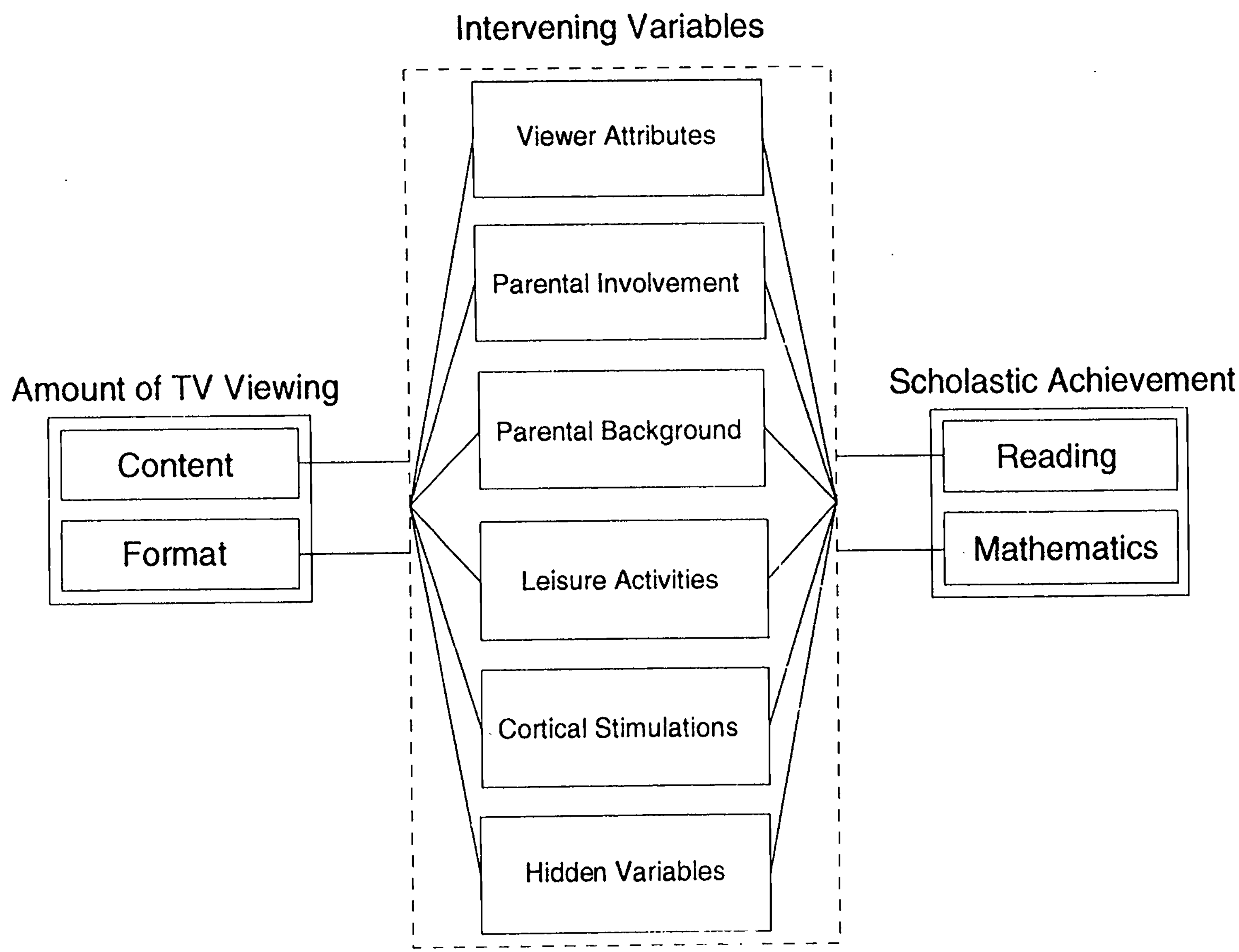
Figure 3. An example of a neural network with 3 input nodes and 1 output node, with 5 hidden nodes on 2 hidden layers. Also shown, are 3 of the 17 weights.

Figure 4. Neural network estimates of mathematics scores, and the errors, as a function of television viewing hours. Also plotted are the curves for boys and girls, separately.

Figure 5. Neural network estimates of mathematics scores as a function of television viewing hours for three socioeconomic levels.

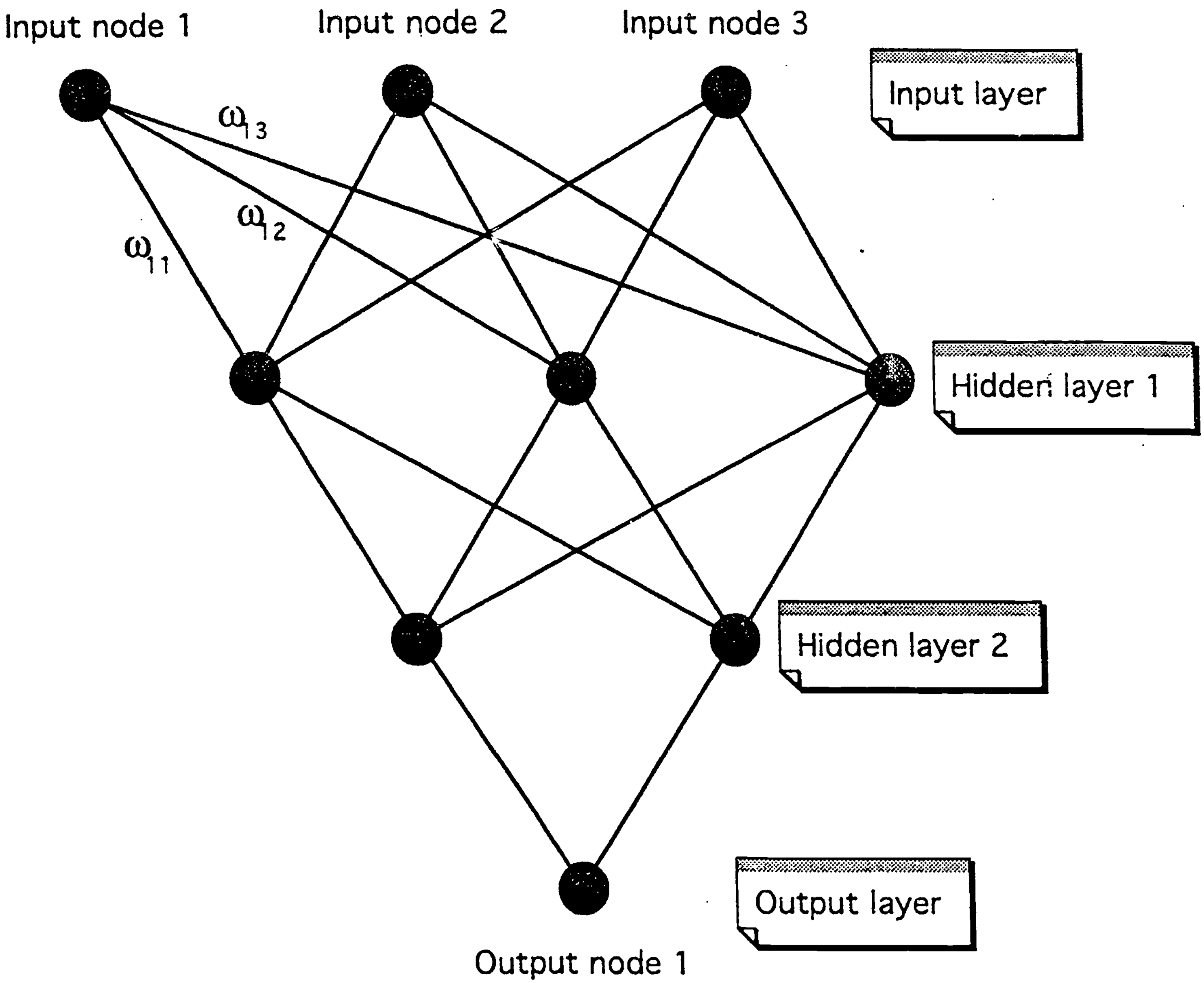
Figure 6. Neural network estimates of mathematics scores as a function of television viewing hours for five ability levels: mean-3σ, mean-2σ, mean-1.5σ, mean, and mean+3σ.

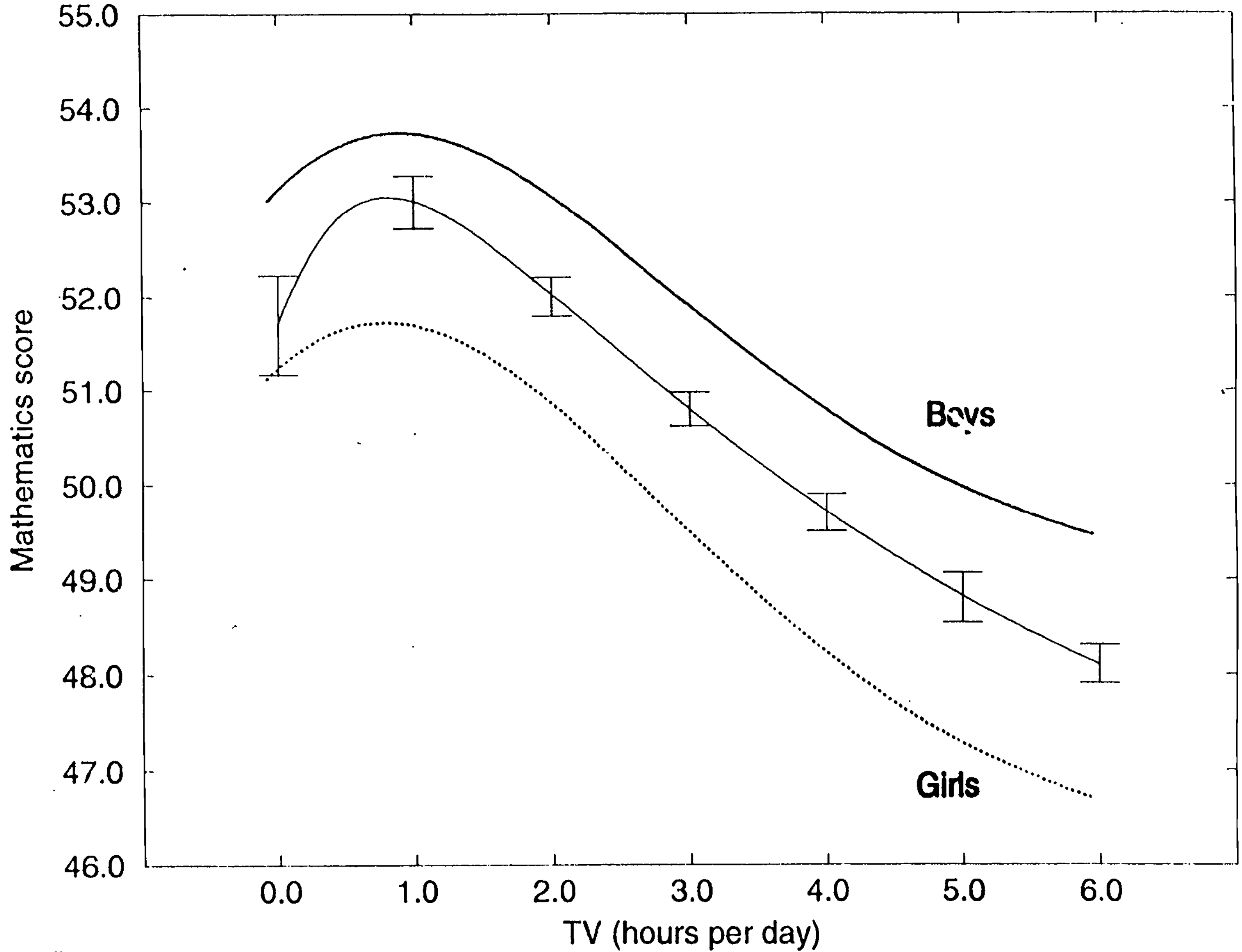

Hypothesis:
Process:
Sign:
Displacement
Amount of Viewing
Out of School Activities
Scholastic Achievement
-
Concentration-deterioration
Content
Scholastic Achievement
-
Passivity
Format
Cortical Stimulations
Reading
-
Math
-
Hemispherical Specialization
Format
Cortical Stimulations
Reading
-
Math
+
Interest Stimulation
Learning of Instrumental Informaion
Learning of School-equivalent Content
Content
Scholastic Achievement
+
Learning of New Cognitive Skills
Excitation-transfer
Format
Cortical Stimulations
Scholastic Achievement
+

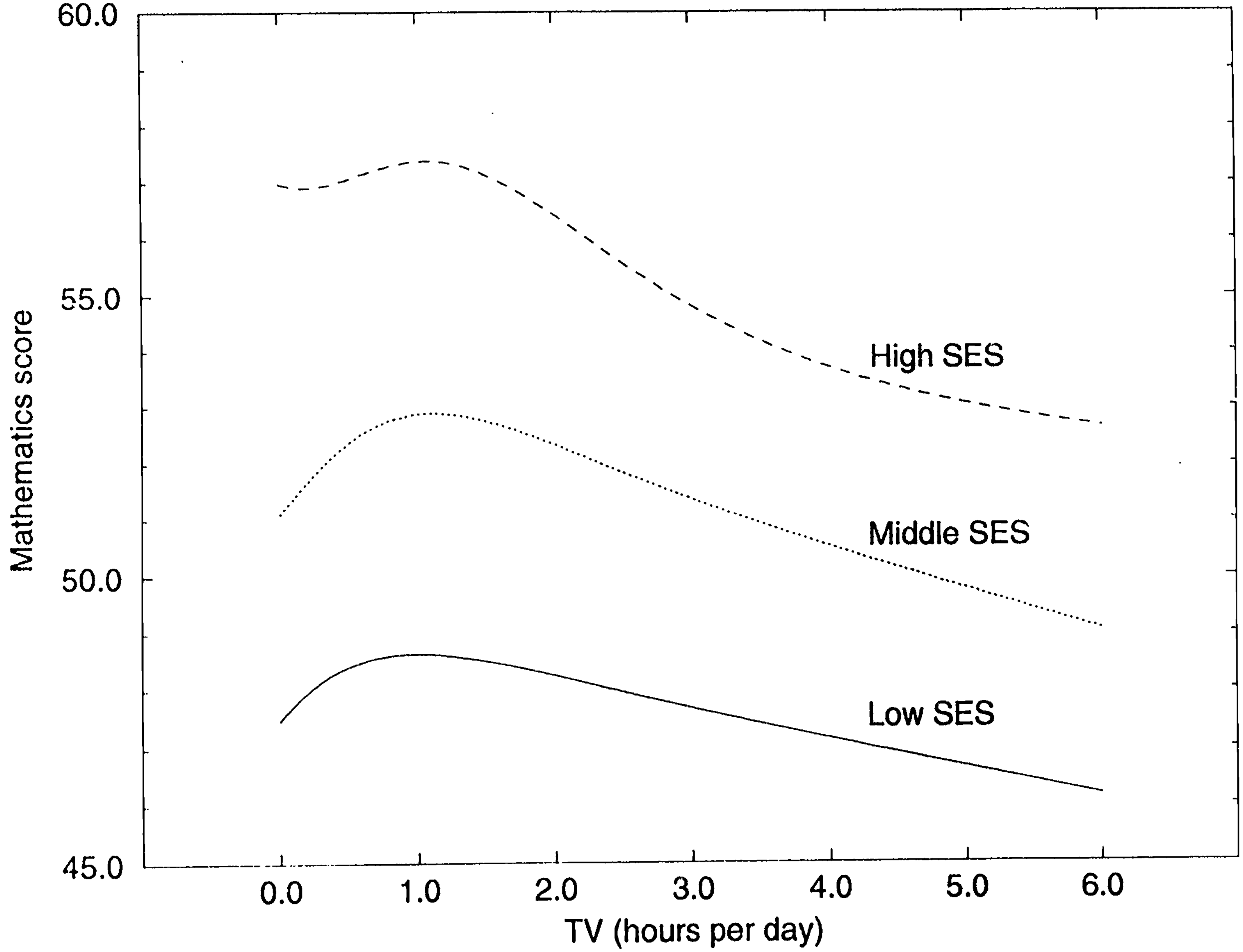

Intervening Variables
Amount of TV Viewing
Content
Format
Viewer Attributes
Parental Involvement
Parental Background
Leisure Activities
Cortical Stimulations
Hidden Variables
Scholastic Achievement
Reading
Mathematics

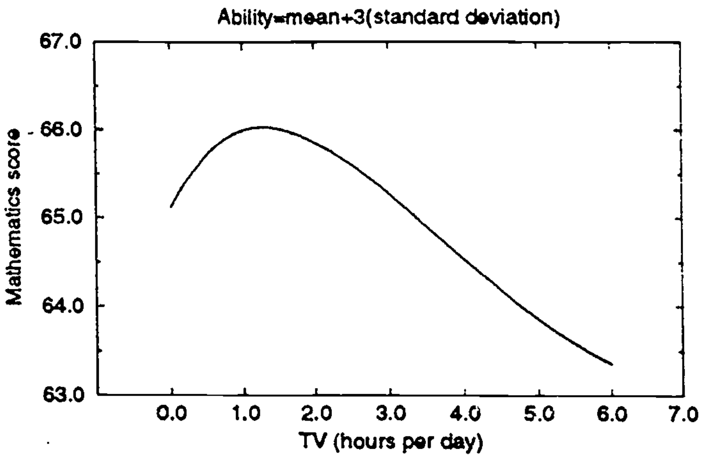
35

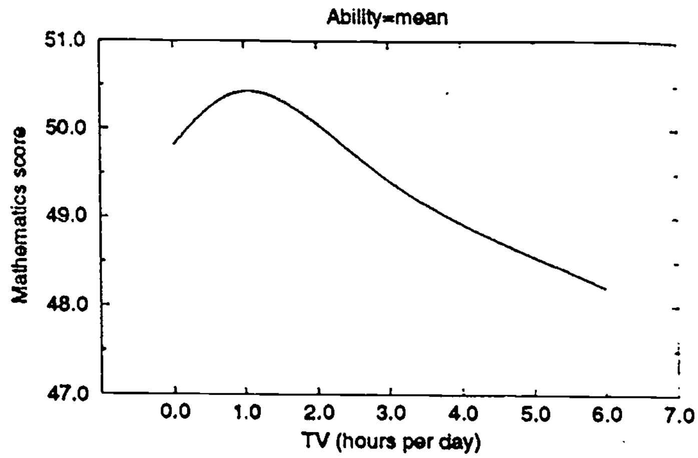
36

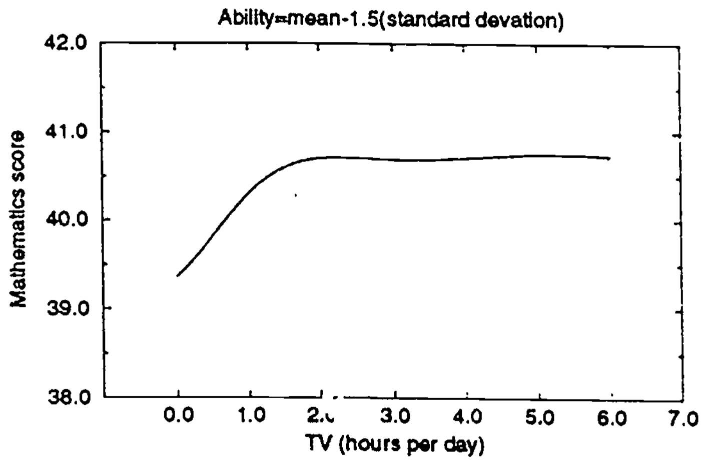

Input node 1
Input node 2
Input node 3
Input layer
ω_{13}
ω_{12}
ω_{11}
Hidden layer 1
Hidden layer 2
Output layer
Output node 1

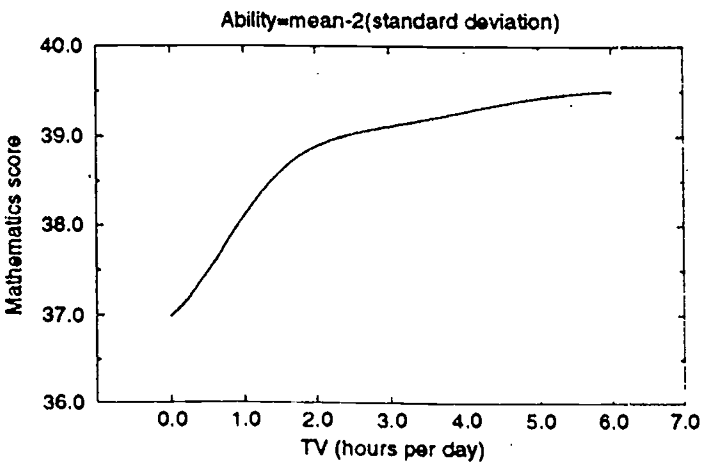

55.0
54.0
53.0
52.0
51.0
50.0
49.0
48.0
47.0
46.0
Mathematics score
0.0
1.0
2.0
3.0
4.0
5.0
6.0
TV (hours per day)
Boys
Girls

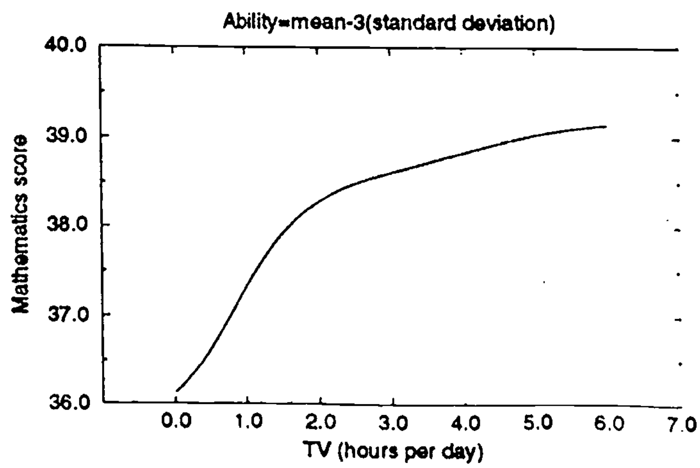

60.0
55.0
50.0
45.0
Mathematics score
High SES
Middle SES
Low SES
0.0
1.0
2.0
3.0
4.0
5.0
6.0
TV (hours per day)


Ability=mean+3(standard deviation)
Mathematics score
67.0
66.0
65.0
64.0
63.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
TV (hours per day)


Ability=mean
Mathematics score
51.0
50.0
49.0
48.0
47.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
TV (hours per day)


Ability=mean-1.5(standard devation)
Mathematics score
42.0
41.0
40.0
39.0
38.0
0.0
1.0
3.0
4.0
5.0
6.0
7.0
TV (hours per day)


Ability=mean-2(standard deviation)
Mathematics score
40.0
39.0
38.0
37.0
36.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
TV (hours per day)


Ability=mean-3(standard deviation)
Mathematics score
40.0
39.0
38.0
37.0
36.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
TV (hours per day)